CONTRACT AF 33(616)—8438
PROJECT 7381; TASK 738103

ZINC SELENIDE

Data Sheets

M. Neuberger

DS-132
September 1963

EPIC

ELECTRONIC
PROPERTIES
INFORMATION
CENTER

HUGHES

HUGHES AIRCRAFT COMPANY
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FOREWORD

This report was prepared by Hughes Aircraft Company under Contract No. AF 33(616)-8438. The contract was initiated under Project No. 7381, Task No. 738103. The work was administered under the direction of the Directorate of Materials and Processes, Aeronautical Systems Division, with Mr. R.F. Klinger acting as Project Engineer.

Many persons have contributed to the program which this report represents. The author wishes especially to acknowledge the contributions of the following: J.J. Anders, J.W. Atwood, C.L. Blocher, D.L. Grigsby, J.J. Grossman, F.S. Harter, D.H. Johnson, H.T. Johnson, J.T. Milek, and E. Schafer.

ABSTRACT

The Electronic Properties Information Center has been established to collect, index and abstract the literature on the electrical and electronic properties of materials and to evaluate and compile the experimental data from that literature. A modified coordinate index to the literature is machine stored and printed for manual use. The Center publishes data sheets, summary reports, thesauri, glossaries, and similar publications as sufficient information is evaluated and compiled. This report consists of the compiled data sheets on Zinc Selenide.

This report has been reviewed and is approved for publication.

H. Thayne Johnson, Supervisor
Electronic Properties Information Center

John W. Atwood
Project Manager

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INTRODUCTION

In June 1961, a program was initiated under the direction of the Air Force to collect, index and abstract the literature on the electrical and electronic properties of materials and to evaluate and compile the experimental data from that literature. Placed at Hughes Aircraft Company in Culver City, California, the program, now called the Electronic Properties Information Center, was originally intended to cover ten major categories of materials: Semiconductors, Insulators, Ceramics, Ferroelectrics, Metals, Ferrites, Electroluminescent Materials, Ferromagnetics, Thermionic Emitters, and Superconductors.

During the first year, studies were completed on the Semiconductor and Insulator categories; and Ceramics was discontinued as a separate category and subsumed under the other nine. Vocabulary studies have now been completed on all categories, and retrospective documentation is virtually complete for Semiconductors and Insulators. A full index to the literature is maintained; and publications such as data sheets, summary reviews, glossaries, and thesauri are periodically issued. The use of the Center and these publications are available to anyone wishing information within the scope of the Center's objectives. A full list of publications to date appears at the end of this report.

This report contains data sheets on Zinc Selenide. The data sheets have been compiled direct from the literature. Articles are allowed to accumulate in the system until it is judged that a sufficient number are available on one material for adequate evaluation. The manual

modified coordinate index is then used to retrieve all literature on the material to be compiled. Bibliographies are checked to make sure that valuable and relevant literature is not overlooked. Then the assembled literature is given to the specialist doing the evaluation and compilation.

Evaluation is confined to primary source data except when only secondary citations are available. If equally valid data are available from several sources, all are given. Data are rejected when judged questionable because of faulty or dubious measurements, unknown sample composition, or if more reliable data are available from another source. Selection of data is based upon that which is judged most representative, precise, reliable, and covers the widest range of variables. The addition of new data to a previously evaluated property requires a reappraisal of the reported values. Older data may be deleted if the new data are judged more accurate or representative.

After a thorough analysis and evaluation, the data are compiled into data sheets which present it in its most optimum form. This will be, primarily, but not limited to, curves or tabular form. Where possible, graphs are adapted directly from the original sources. If this is not possible, they are drawn from data compiled from the articles. Where thought important, notes are entered with each graph to help the user. The references, from which the data are drawn, are shown by reference number below each graph with the full bibliographic information at the end of the data sheets. The bibliography is referred to and listed in

the order of entry into the Center (accession number). This provides a quick cross reference into the index used with the literature.

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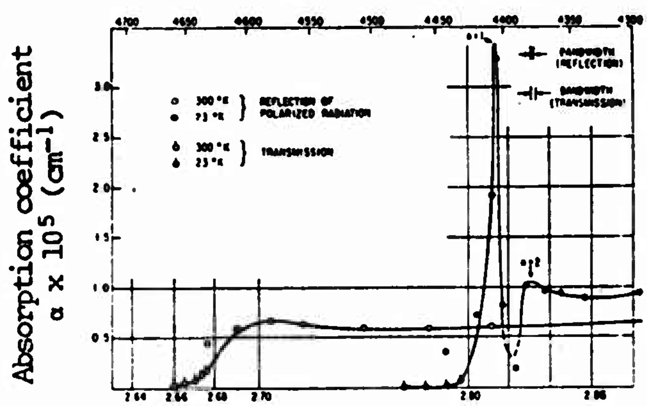
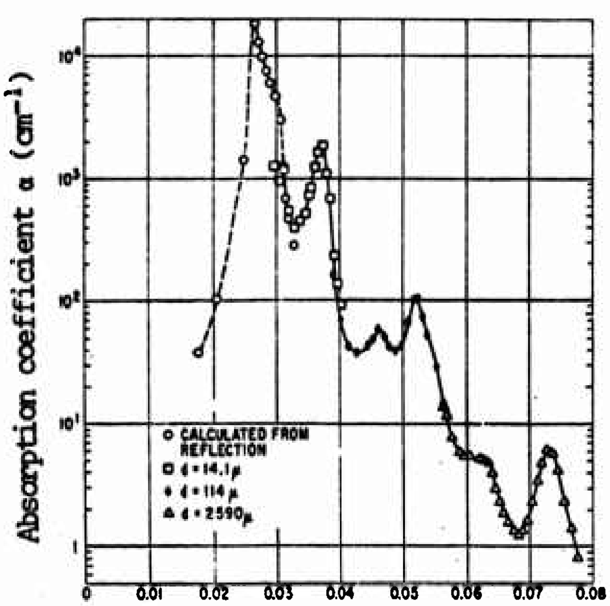
ZINC SELENIDE

Absorption

Absorption coefficient for single crystal zinc selenide in the absorption edge region as a function of photon energy at 300°K and 23°K.



[Ref. 2618]



Absorption coefficient for single crystal zinc selenide in the infrared region as a function of photon energy at 300°K.

[Ref. 2618]

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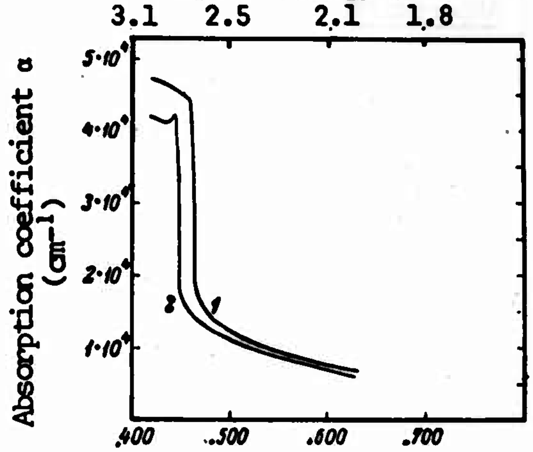
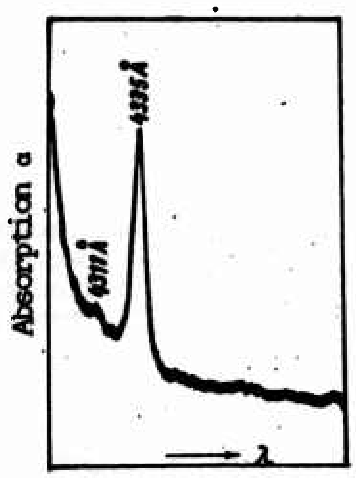
ZINC SELENIDE

Absorption

Spectral distribution curves for the absorption coefficient of intrinsic, polycrystalline zinc selenide films, 0.2-2μ thick. 1) at 393°K; 2) at 77°K.



[Ref. 690]



A microphotometer trace of the spectrum for absorption as a function of wavelength of single crystal, hexagonal zinc oxide. The sample is rotated in the extraordinary ray.
Absorption edge for a 10μ thick sample
α = .4356μ for polarized light normal to c-axis
α = .4292μ for polarized light parallel to c-axis

[Ref. 5942]

ZINC SELENIDE

Absorption

Positions and polarizations of the A, B, and C exciton lines found in the spectra of single crystal, hexagonal zinc selenide at 4.2°K.

	Position	Polarization
A	4335 Å	$E_{\perp}c$
B	4311 Å	$E_{\perp}c$
C	4237 Å	$E_{\parallel}c$

Magnitudes of the valence band splitting energies E_{AB} and E_{AC}.

E_{AB}	E_{AC}
0.016eV	0.066eV

[Ref. 5942]

Wavelengths of spectral lines in edge emission spectrum of single crystal, cubic zinc selenide at 4.2°K and 77°K, type I crystals.*

Wavelengths at 4.2°K (A)	Wavelengths at 77°K (A)
L_1—4410	N_1—4421
L_2—4420	N_2—4436
L_2'—4424	
L_3—4448	
L_3'—4454	
L_{3a}—4499	
L_{3b}—4551	
L_{3c}—4602	
L_{3d}—4654	
L_{3e}—4712	

Wavelengths of spectral lines in edge emission spectrum of single crystal, cubic zinc selenide at 4.2°K and 77°K, type II crystals.*

Wavelengths at 4.2°K (A)	Wavelengths at 77°K (A)
L_1—4420	N_1—4388
L_2—4427	N_2—4590
L_3—4437	N_{2a}—4638
L_4—4453	
L_5—4488	
L_6—4506	
L_7—4512	
L_8—4548	
L_9—4558	
L_{10}—4598	
L_{10a}—4655	
L_{10b}—4712	
L_{10c}—4770	
L_{10d}—4832	

*The two types of crystals may be due to different host lattice defects.

[Ref. 2500]

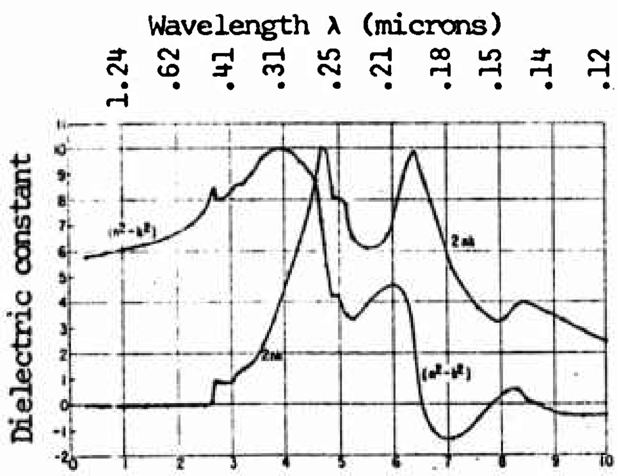
ZINC SELENIDE

Debye Temperature

Symbol	Value	Type	Temperature	Ref.
θ_D	400°K	polycrystalline	80°K	3030

Dielectric Constant

Symbol	Value	Type	Temperature	Ref.
ε_0	9.1	single crystal, cubic	298°K	10288
ε_0	8.1±0.3	single crystal	300°K	2618
ε_∞	5.75±0.1	single crystal	300°K	2618



Real and imaginary parts of the dielectric constant, (n^2-k^2) and 2nk, respectively, for single crystal zinc selenide as a function of photon energy at 300°K. n = refractive index; k = extinction coefficient; n and k are calculated from optical data.

[Ref. 2618]

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ZINC SELENIDE

Effective Mass

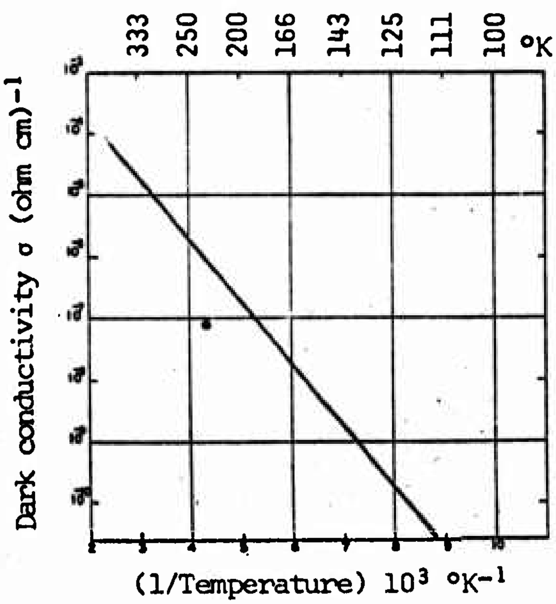
Symbol	Value	Type	Test Conditions
m^*_n	$\sim 0.1\ m_o$	single crystal, n- and p-type	optical measurement, 300°K
m^*_p	$\sim 0.6\ m_o$	single crystal, n- and p-type	optical measurement, 300°K

[Ref. 2618]

Electrical Conductivity

Symbol	Value $(\text{ohm cm})^{-1}$	Dopant	Temperature	Test Conditions
σ	4×10^{-2}	bromine, arsenic	300°K	single crystal, dark conductivity
σ	7×10^{-6}	bromine, antimony	300°K	single crystal, dark conductivity

[Ref. 780]



Dark conductivity as a function of temperature for single crystal zinc selenide doped with bromine and antimony.

[Ref. 780]

SEMICONDUCTOR MATERIALS

September 1963

ZINC SELENIDE

Electrical Resistivity

Symbol	Value	Type	Temperature	Ref.
ρ	10^8 to 10^9 ohm cm	0.2 to 2μ thick films polycrystalline, pure	300°K	690

Electroacoustic Properties

Symbol	Value	Type	Temperature		Ref.
LO	0.031 eV	single crystal	300°K	optical data	2618
TO	0.026 eV				
LO	0.03 eV		4.2°K	optical data	2500
TO	0.027 eV				

Energy Bands

Symbol	Value	Temperature	Test Conditions
dE_g/dP	6.0×10^{-6} eV/atm	300°K	single crystal, pure, experimental wave-length, λ= .481μ [Ref. 273]
	0.49×10^{-6} eV/atm (maximum shift)	300°K	
	-2.0×10^{-6} eV/atm	300°K	
dE_g/dT	7.2×10^{-4} eV/°K	90 - 400°K	single crystal, pure [Ref. 826]

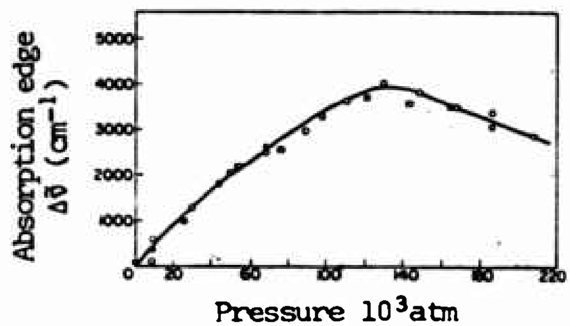
SEMICONDUCTOR MATERIALS

September 1963

ZINC SELENIDE

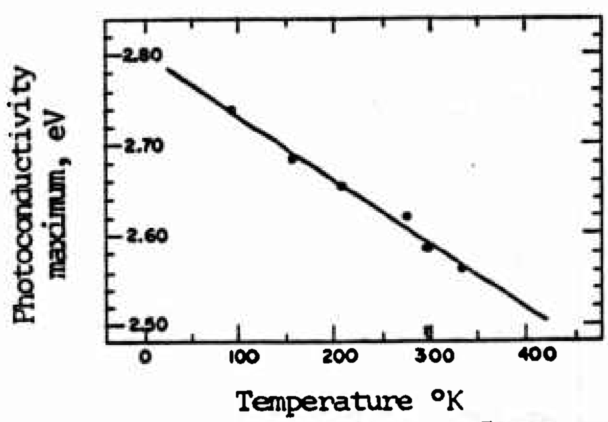
Energy Bands

Shift of zinc selenide absorption edge with pressure (ν_0 = 20,800 cm^{-1}, α = 65 cm^{-1}). Samples are single crystal, pure.



[Ref. 273]

The location of the photoconductivity maximum (or maxima) as a function of temperature for single crystal zinc selenide.



[Ref. 826]

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ZINC SELENIDE

Energy Gap

Symbol	Value	Type	Temperature	Ref.
E_g	2.9 (calc.) 2.59 2.47 2.38	polycrystalline film, zincblende symmetry, 1μ film, optical-absorption measurement	0°K 295°K 398°K 496°K	10250
E_g	2.67	single crystal	297°K	5201
E_g	2.6	polycrystalline film	300°K	7174
E_g	2.786	polycrystalline film	77.3°K	634
E_g	2.81±0.01	single crystal electro-optical	4°K	2618
E_g	2.83	cubic	4.2°K	2500

Energy Levels

Symbol	Value (eV)	Dopant	Type	Ref.
E_D	0.21	Bromine	single crystal	780
E_A	0.6	Copper	single crystal	780
E_A	0.6	Silver	single crystal	780
E_A	0.7	Antimony	single crystal	780

Energy gaps calculated from reflectance data. Double entries correspond to peaks split by spin-orbit interaction. Sample is single crystal. Temperature = 300°K.

Energy transitions	$L_{3'} \rightarrow L_1$	$L_{3'} \rightarrow L_3$	$X_4 \rightarrow X_1$ $X_5 \rightarrow X_1$	$X_5 \rightarrow X_3$(?)
	4.9 5.3	9.1 9.6	6.7	8.5

[Ref. 5949]

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ZINC SELENIDE

Energy Levels

Transitions at the L-absorption edge showing spin orbit splitting of the L_3 valence band in thin film zinc selenide, cubic sample.

Value (eV)	Temperature (°K)
4.94	20
4.92	78
4.89	200
4.80	297

[Ref. 2850]

Exciton absorption peaks associated with valence and conduction bands at Γ for single crystal zinc selenide at 4°K. Principal peak at 2.81 ± 0.01 eV.

	1st. peak at Γ	2nd. peak at L
Exciton transition	2.7 eV	4.75 eV
Interband transition	3.15 eV	5.1 eV
Spin orbit valence-band split	0.45 eV	0.35 eV

[Ref. 2618]

Mobility

Symbol	Value	Type		Ref.
μ_n	530 $cm^2(Vsec)^{-1}$	single crystal, n-type, ρ=1 ohm cm	300°K	5954
μ_n	∿ 100 $cm^2(Vsec)^{-1}$		300°K	2911

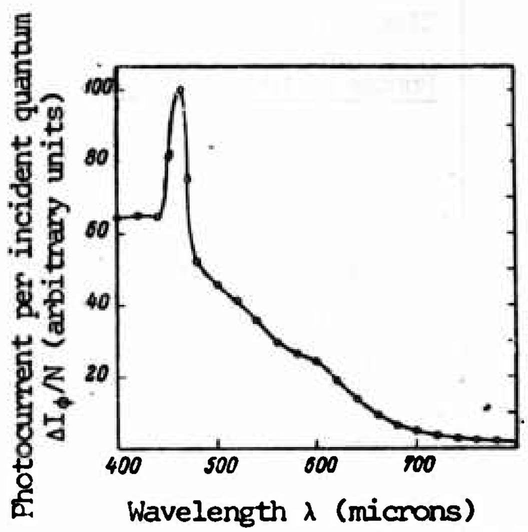
Material	Temp. range (°C)	Mobility (cm^2/v-sec) Electrons	Holes	Carrier concentration (cm^{-3}) 27°C	200°C
ZnSe:Cu	200–400		11	...	10^{10}
ZnSe:Cu, Se-fired	130–260		16	...	10^{11}
ZnSe, Se-fired	200–400		15	...	10^{10}
ZnSe:Ga	27–400	80		10^{6}	...
ZnSe:Ga, Zn-fired	27	150		10^{15}	...
ZnSe, Zn-fired	27–250	260		10^{16}	...

Mobility and carrier concentration for single crystal zinc selenide, variously doped at temperatures from 300°K to 673°K.

[Ref. 2618]

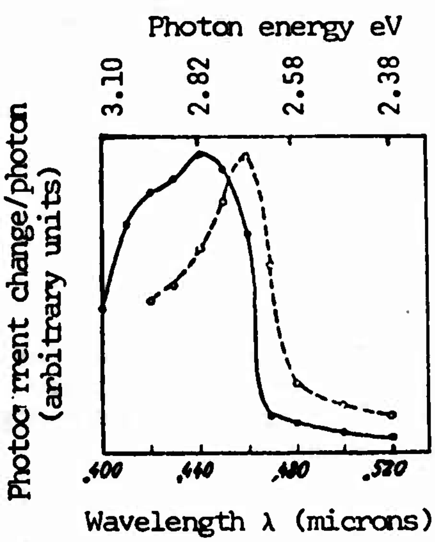
ZINC SELENIDE

Photoelectronic Properties



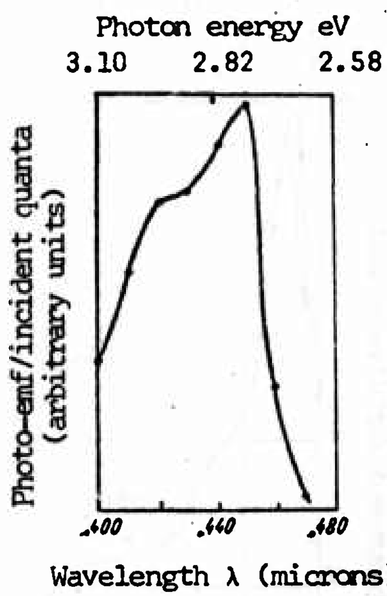
Spectral distribution curves for the photoconductivity of intrinsic, polycrystalline zinc selenide films, 0.2 - 2μ thick at 300°K.

[Ref. 690]



Decrease in electrical conductivity on illumination in a polycrystalline zinc selenide film. The broken curve indicates photoconductivity.

[Ref. 622]



The photo-emf response spectrum of a polycrystalline zinc selenide sample.

[Ref. 622]

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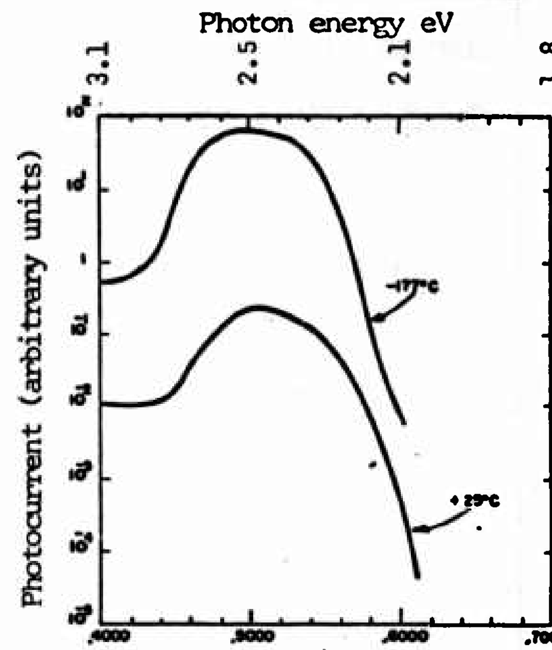
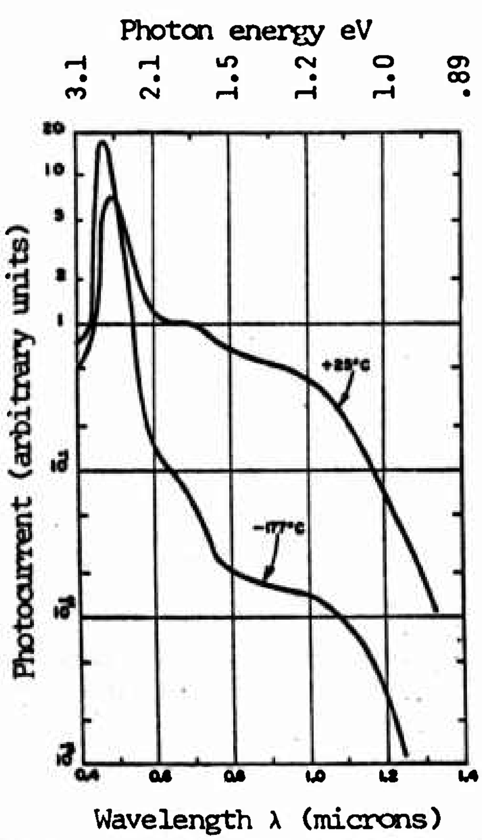
ZINC SELENIDE

Photoelectronic Properties



Spectral response curves for photoconductivity in single crystal, bromine-silver-doped zinc selenide.

[Ref. 780]



Spectral response curves for photoconductivity in single crystal, bromine-antimony-doped zinc selenide.

[Ref. 780]

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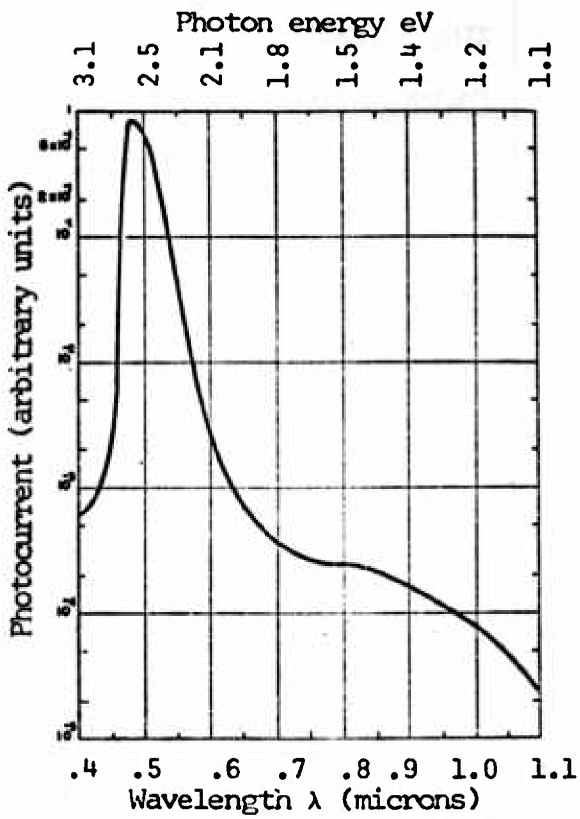
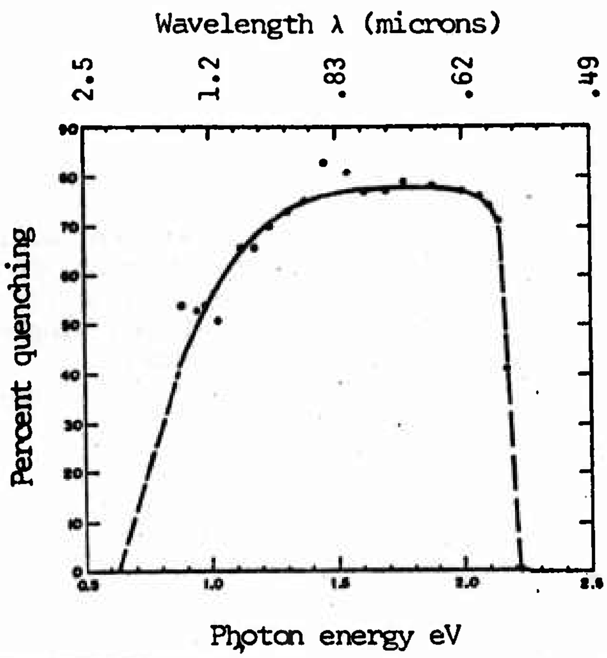
ZINC SELENIDE

Photoelectronic Properties

Spectral response curve for photoconductivity in single crystal, bromine-arsenic-doped zinc selenide.



[Ref. 780]



Infrared quenching spectrum for single crystal, bromine-copper-doped zinc selenide at 50°K.

[Ref. 780]

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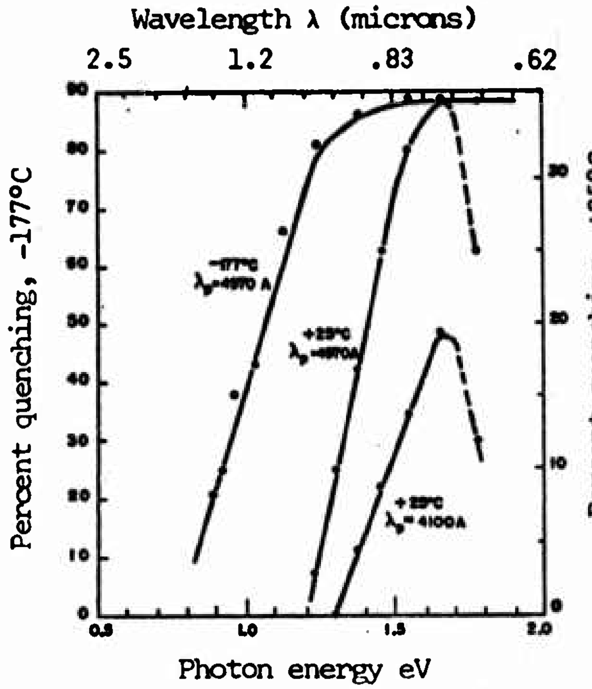
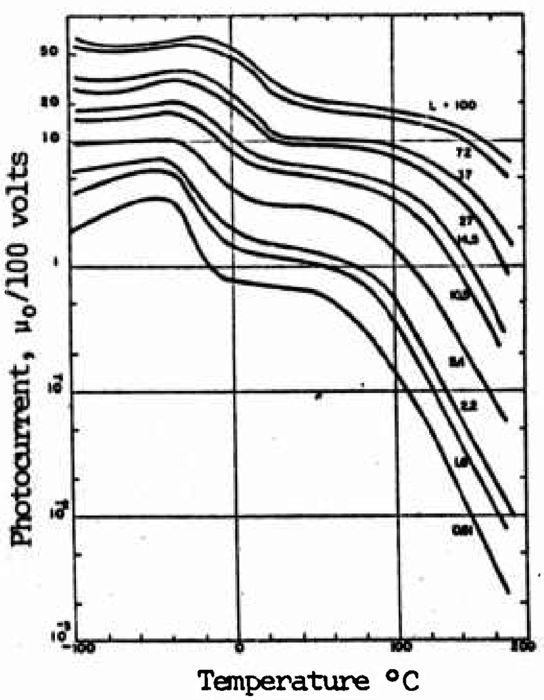
Photoelectronic Properties



Infrared quenching spectra for single crystal, bromine-antimony-doped zinc selenide.

[Ref. 780]



Variation of photocurrent with temperature for different photo-intensities of excitation for bromine-antimony-doped, single crystal zinc selenide.

[Ref. 780]

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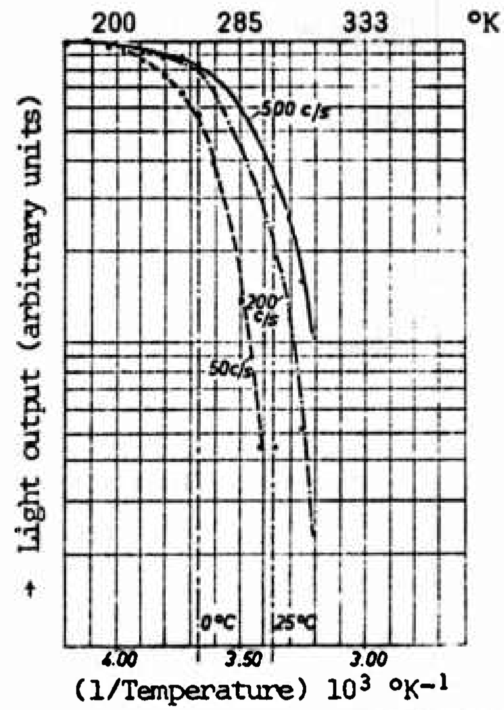
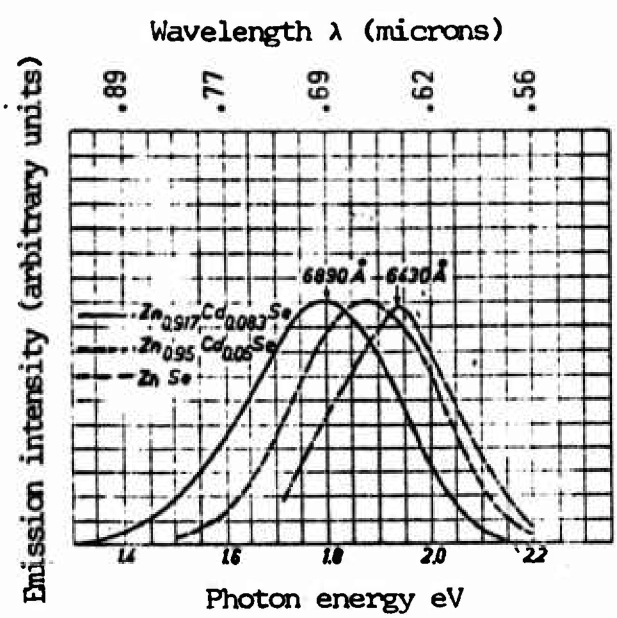
Photon Electroluminescence



Photon Electroluminescence: light output as a function of temperature for a copper-aluminum-doped zinc selenide red phosphor.

[Ref. 6458]



Emission intensity as a function of wavelength for a copper-aluminum-doped zinc selenide red phosphor and a mixed zinc cadmium selenide phosphor.

[Ref. 6458]

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ZINC SELENIDE

Piezoelectric Properties

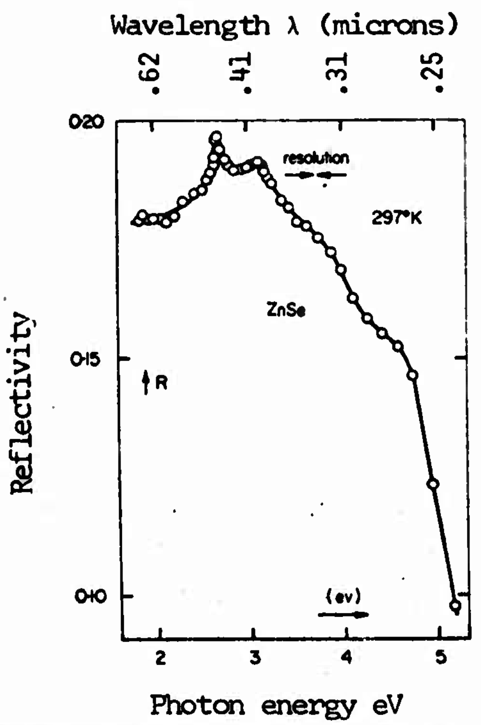
Symbol	Value	Type	Temperature	Ref.
d_{31}	0.31×10^{-12}	single crystal, cubic	298°K	10288
d_{14}	1.10×10^{-12}			

Reflectivity

	Type	Temperature
Maximum reflectivity at .4242μ	single crystal, hexagonal	4.2°K
Minimum reflectivity at .4232μ		

(polarized light parallel to c-axis)

[Ref. 5942]



Reflectivity spectrum of single crystal, cubic zinc selenide as a function of wavelength at 297°K.

[Ref. 3935]

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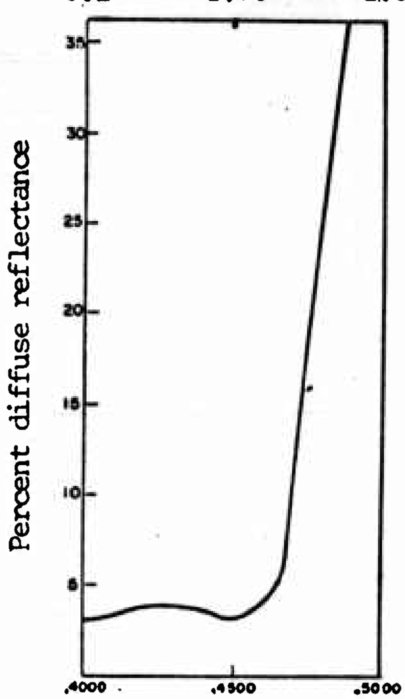
ZINC SELENIDE

Reflectivity

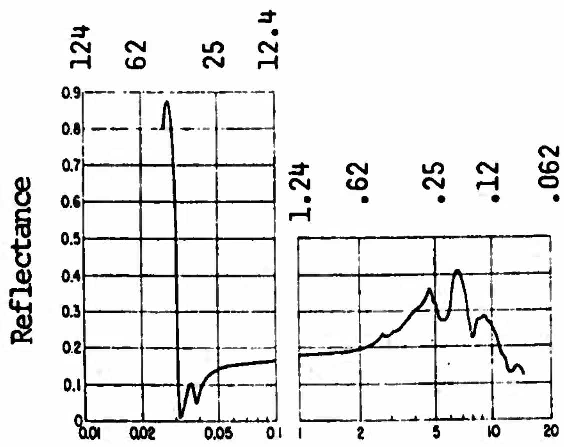
Photon energy eV



Wavelength λ (microns)
[Ref. 914]

Diffuse reflectance spectra of polycrystalline zinc selenide at 300°K.

Wavelength λ (microns)



Photon energy eV

Reflectance of single crystal zinc selenide for near-normal incidence as a function of photon energy at 300°K.
[Ref. 2618]

ZINC SELENIDE

Refractive Index

Symbol	Value		Ref.
n	2.89	$\lambda = .589\mu$	7359

Thermal Conductivity

Symbol	Value		Temperature	Ref.
k	33×10^3	cal/cm sec deg	300°K	636
k	$30\text{-}33 \times 10^3$	cal/cm sec deg		3477

ZINC SELENIDE REFERENCES

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